**ENERGY MANAGEMENT SYSTEM**

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**This thesis is submitted as partial fulfillment of the requirement for the award of the degree of Bachelor of Electrical Engineering (Electronics)**

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the degree of Bachelor of Electrical Engineering (Electronics)"

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Date : 23 APRIL 2009

# DEDICATION

***Specially dedicated to***

***My beloved parents, lecturer,***

***and all of my best friends.***

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## ABSTRACT

This project report describes the design and implementation of the computer system Home Energy Management System. The system provides a user the ability to differentiate between and limit the use of major power consuming appliances, allowing them to save energy and monitoring power usage at home. This system is developed to manage the power consumption in daily life. By creating this system the power usage will be consume wisely without any waste. This system control or limited the power consumption by turn off the electrical appliance when the amounts of power consumption exceed the limit. The user can set the desired amount of power usage in daily in order to save power consumption. It also allows the user to see the consumption rate for difference appliance in their house by monitor power consumption on LCD display. Buttons are used to select which parameter (voltage. current and power consumption) to be monitored. The system required three main parts include on hardware and software which is power source, controlling unit and monitoring system. The system used as PIC16F877A as a controller and ADE7753 where offer measured analog voltage and current input. The analog inputs are sample by ADC within the ADE7753, and their magnitude and phases are used to digitally calculate real, reactive and complex power in the line.

# ABSTRAK

Laporan projek menerangkan berkenaan rekaan dan applikasi system berkomputer bagi Sistem Pengurusan Tenaga. Sistem ini menyediakan kemudahan utuk pengguna bagi membezakan diantara kawalan serta penggunaan kuasa eletrik dimana membantu pengguna menguruskan penggunaan elektrik dengan cermat.Dengan adanya system ini penggunaan elektrik akan lebih terkawal tanpa ada pembaziran berlaku.Sistem ini beroperasi dengan cara mengawal atau menghadkan penggunaan elektrik sekiranya penggunaan elektrik melebihi had yang ditetapkan.Kadar kawalan penggunaan elektrik ini boleh ditentukan oleh penguna itu sendiri.Pengguna juga boleh melihat atau memerhatikan kadar penggunaan elektrik bagi setiap perkakas elektrik di paparan skrin.Parameter seperti voltan, arus serta penggunaan kuasa boleh juga dipaparkan di skrin dengan menekan suis butang.Sistem ini terbahagi kepada tiga bahagian termasuk litar dan program elektrik seperti sumber kuasa, unit kawalan dan sistem paparan.Sistem ini menggunakan mikro cip PIC16F877A sebagai kawalan dan ADE7753 dimana menyediakan utuk pengukuran kemasukan analog voltan dan arus.Kemasukan analog dijadikan sebagai bahan utuk ADC (penukaran bentuk analog kepada system digital) didalam ADE7753 dan keluaran magnitude dan fasa daripada hasil tersebut digunakan utk pengiraan kuasa.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| CPU | Central Processing Unit |
| I/O | Input and Output |
| PC | Personal Computer |
| SSP | Synchronous Serial Port |
| SPI | Serial Peripheral Interface Protocol |
| CS | Chip Select |
| LCD | Liquid Crystal Display |
| SCK | Serial Clock |
| DC | Direct Current |
| USART | Universal Serial Asynchronous Receiver Transmitter |
| RS | Register Select |
| R/W | Read/Write |
| E | Enable |
| SDI | Serial Data In |
| SDO | Serial Data Out |
| ROM | Read Only Memory |
| RAM | Random Access Memory |
| PCB | Printed Circuit Board |
| GND | Ground |
| ADC | Analog to Digital Converter |
| AMR | Automatic Meter Reading |
| GUI | Graphic User Interface |
| VB | Visual Basic |
| LED | Light Emitted Diode |
| MSB | Most Significant Bit |

| | |
|---|---|
| LSB | Least Significant Bit |
| EMF | Electromagnetic Fields |
| PBP | PicBasic Pro compilers |
| IDE | Integrated Development Environment |
| ICD | In Circuit Debugging |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Energy Management System can also refer to a computer system which is designed specifically for the automated control and monitoring power usage at home. This system is developing to manage the power consumption in daily life. By creating this system the power usage will be consume wisely without any waste. This system control or limited the power consumption by turn off the electrical appliance when the amounts of power consumption exceed the limit. It also allows the user to see the consumption rate for difference appliance in their house by monitor power dissipation on LCD display and Personal Computer (PC).However the PC only receive the measured value of current and voltage, then user can interface with PC to determine the set point to be sent to the microcontroller. In doing this, user definitely can disable certain appliance when total power consumption is exceed the limit.

By using this system, the user can set the desired amount of power usage in daily in order to save power consumption. Besides that, user could find the suitable range of time to use the appliance which is consuming major power will cause the higher amount of power dissipation. The system also can manipulated the electrical appliance with automatically or manually turn on and off. This system will be expect to become an intelligent management where it such a good way to save the usage of power consumption in daily life.

The system required three main parts include on hardware and software which is power source, controlling unit and monitoring system. The system used a PIC16F877A as a controller. Basically, this project is designed to be interface with home electrical appliance based on development of Graphical User Interface (GUI) in Visual Basic 6.0.For advances features of this system the control unit will able to stand-alone running or work independently base on the program that been set in control unit to be automatically react to the data such in order to manipulate the energy consumption patterns without connected to the PC. This is important causes the usage of PC 24 hours will draw a lot of power that will affect on this system and bad effect to our self.

## 1.2 Research Problem

Rising electricity prices have made it worthwhile for consumers to be informed about the costs of operating their appliances. All types of consumers of electricity, from landlords to office managers to the simple home user, are seeking more and more information about the power consumption of their appliances and electronics in an effort to reduce power usage and save money. It can be difficult to obtain power consumption data for most appliances and electronics, and consumers often aren't sure of the best ways in which to reduce power consumption. For years, large-scale industry has spent millions of dollars on equipment and services in an effort to reduce its power consumption, but there is little such practical and affordable help available to home and small office consumers.

## 1.3 Objective

The higher goals were to not only build a cheaper, more accurate and more functional device, but also provide some means by which the characterization of a load could help save power. To achieve this aim, the study is carried out for the following objectives.

i. To develop a system function to be as meter for current, voltage and power reading and also function as an automatic meter reading which is calculated the amount of power usage especially for management of various load at home.

ii. To develop system where control the appliance by turn on and off automatically through a PC where the system able to work independently base on program that has been set in control unit to manipulate the electrical appliance.

## 1.4 Scope of Project

i. To develop energy management system that view measurement of voltage (rms), current (rms) and power consumption on LCD display and using PIC16877A as a controller for this system.

ii. To integrate the hardware and software in order to develop an energy management system by interfacing of electrical appliance

iii. Develop Graphical User Interface (GUI) using Visual Basic for hardware and software interfacing.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In various countries, there are presently attempts to replace electro-mechanical power meters with electronic ones. Although the module described in this article was not specifically designed for that purpose, it can be used as a low cost electronic power meter module for simple domestic electric power measurement applications. Some of its advantages over conventional systems are life expectancy and accuracy and the possibility of remote monitoring [1]

The circuit system is implemented with a power measurement IC (ADE7753) from Analog Devices. It is capable of measuring instantaneous voltage, current, and power, VRMSI,m s, and real. Reactive and apparent energy. The interface to the mains of a site is accomplished using a novel, non-intrusive flexible Rogowski coil developed as the current sensor. [2]

The ADE7753 is a highly accurate energy metering integrated circuit. It has the ability to calculate active, reactive and apparent energy. This chip can communicate via serial data transfer and has a pulse output frequency proportional to the active power measured. [7]

“LCD is used because it consumes less power than seven segment display. It is responsible for cycling through various modes as commanded by the user in order to display various power consumption data". [8]

The PIC16F877A was chosen for its SPI mode synchronous serial communication and large number of general I/O pins available. [7]

## 2.2 Component review

This section provides the necessary background information required for a proper understanding of the content discussed in this paper. This includes:

### 2.2.1 ADE7753 Chip

In this project, ADE7753 IC chip from Analog Devices are used for measuring electric appliance. This chip is based on an inexpensive shunt resistor.

### 2.2.2 Microchip PIC 16F877A

The Microcontroller primarily performs the function of converting the analog signal inputs into an 8 bit digital value. It performs basic measurements on the waveforms to obtain the average power and displays this on a 2 x 16, on green LCD display. To use a microcontroller in this project, all operation as states below are should be know.

#### 2.2.2.1 Crystal operation

These circuits are used as a clock input for microcontroller to control the internal clock generator circuitry.

#### 2.2.2.2 Reset circuit

This circuit is used as an input to initialize the PIC16F877A to a know start up state.

#### 2.2.2.3 I/O circuit

In microcontroller, the input and output device are needed for develop system function. This section will describe in detail about the input and output circuit.

### 2.2.3 Liquid Crystal Display (LCD)

In this section described LCD as a monitoring system in develop this project.

### 2.2.4 Optocoupler

Describe the function of this device as an isolation using in Energy Management System.

### 2.2.5 Serial Peripheral Interface Protocol.

This topic will describe the way to communicate with one or more slave devices.

### 2.2.1 ADE7753 Chip

The ADE7753 is a highly accurate energy metering integrated circuit. It has the ability to calculate active, reactive, and apparent energy. This chip can communicate via serial data transfer and has a pulse output frequency proportional to the active power measured. This chip requires analog inputs of voltage and current applied to its input terminals. The maximum differential signal level is ± .5 volts with respect to AGND. The gain of both of these channels can be changed to account for error in the transformers. There is a selectable on-chip digital integrator which can provide an interface to a current sensor like a Rogowski coil. The analog to digital conversion in the ADE7753 is achieved by using two second-order Σ-Δ ADCs. The sampling rate is determined by the sampling clock which is equal to the input clock divided by four. There are many system calibration features in this chip including channel offset correction, phase calibration, and power calibration. This allows it to provide very accurate power information. The ADE7753 power measurement chip met all our operating specifications. This chip is capable of measuring single phase power with several built in calibration points for precise power measurement. The chip communicates via serial communication which can be easily integrated with a PIC microprocessor. The chip has 24 bit internal registers which are used to accumulate the power measured. This data can be read using a serial peripheral interface with the chip

### 2.2.2 Microchip PIC 16F877A

The Microchip PIC16F877A is an inexpensive 8-bit microcontroller. Its features include 256 bytes of EEPROM data memory, self programming, two Comparators, eight channels of 10-bit Analog-to-Digital (A/D) converter, a Synchronous Serial Port (SSP), a Universal Serial Asynchronous Receiver Transmitter (USART), and three separate timer modules. It contains 14.3KB worth of program memory and is capable of operating with up to a 20MHz clock (200ns instruction cycle). The primary functionality for the PIC in the EMS is to perform a serial read on the active energy register on the ADE chip. Secondary functions include turning the EMS on and off. The PIC16F877A was chosen for its SPI mode synchronous serial communication and large number of general I/O pins available.

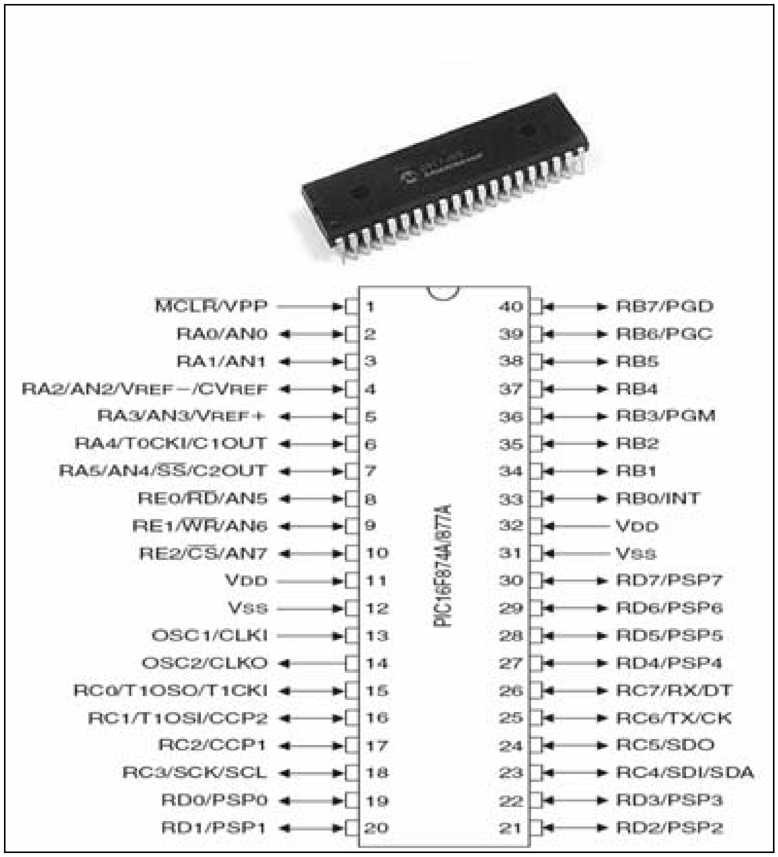


**Figure 2.1:** Pin out for the 40-pin PDPIP package of the PIC16F877A

### 2.2.2.1 Crystal operation

As shown in Figure 2.2, in this mode of operation an external crystal and two capacitors are connected to the OSC1 and OSC2 inputs of the microcontroller. The capacitors should be chosen as in Table 2.1. For example, with a crystal frequency of 4 MHz, two 22 pF capacitors can be used

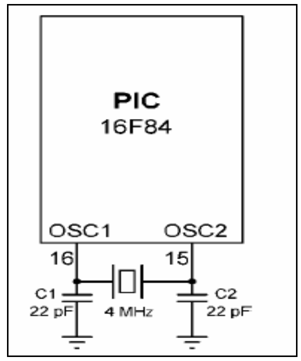


**Figure 2.2** Crystal oscillator circuit

**Table 2.1:** Capacitor selection for crystal operation

| Mode | Frequency | C1, C2 |
|---|---|---|
| LP | 32 kHz | 68–100 pF |
| LP | 200 kHz | 15–33 pF |
| XT | 100 kHz | 100–150 pF |
| XT | 2 MHz | 15–33 pF |
| XT | 4 MHz | 15–33 pF |
| HS | 4 MHz | 15–33 pF |
| HS | 10 MHz | 15–33 pF |

### 2.2.2.2 Reset circuit

Reset is used to put the microcontroller into a known state. Normally when a PIC microcontroller is reset execution starts from address 0 of the program memory. This is where the first executable user program resides. The reset action also initializes various SFR registers inside the microcontroller. PIC microcontrollers can be reset when one of the following conditions occur:

● Reset during power on (POR – Power On Reset)

● Reset by lowering MCLR input to logic 0

● Reset when the watchdog overflows.

As shown in Figure 2.3, a PIC microcontroller is normally reset when power is applied to the chip and when the MCLR input is tied to the supply voltage through a 4.7 K resistor.

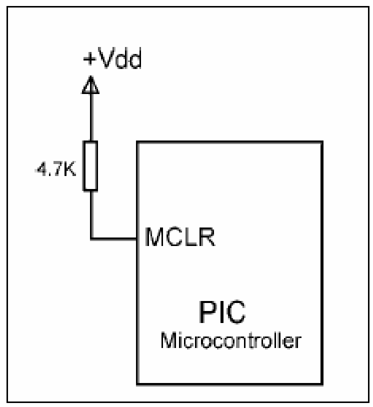


**Figure 2.3** Using the power on reset

There are many applications where we want to reset the microcontroller, e.g. by pressing an external button. The simplest circuit to achieve an external reset is shown in Figure 2.4. In this circuit, the MCLR input is normally at logic 1 and the microcontroller is operating normally. When the reset button is pressed this pin goes to logic 0 and the microcontroller is reset. When the reset button is released the microcontroller starts executing from address 0 of the program memory

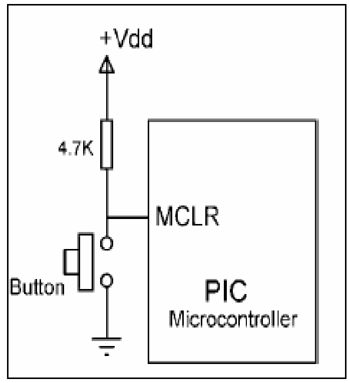


**Figure 2.4:** Using an external reset button

### 2.2.2.3 I/O circuit

A PIC microcontroller port can source and sink 25 mA of current. When sourcing current, the current is flowing out of the port pin, and when sinking current, the current is flowing into the pin. When the pin is sourcing current, one pin of the load is connected to the microcontroller port and the other pin to the ground (see Figure 2.5). The load is then energized when the port output is at logic 1. When the pin is sinking current, one pin of the load is connected to the supply voltage and the other pin to the output of the port (see Figure 2.6). The load is then energized when the port output is at logic 0.

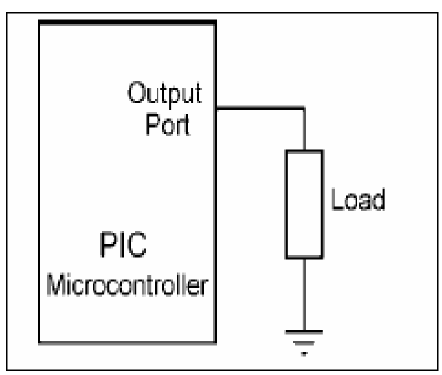


**Figure 2.5:** Current sourcing

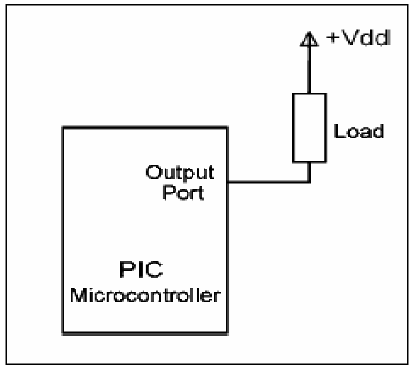


**Figure 2.6:** Current sinking

**LED as an output interface**

LEDs come in many different sizes, shapes, and colours. The brightness of an LED depends on the current through the device. Some small LEDs operate with only a few milliamperes of current, while standard size LEDs consume about 10 mA of current for normal brightness. Some very bright LEDs consume 15–20 mA of current. The voltage drop across an LED is about 2V, but the voltage at the output of a microcontroller port is about 5 V when the port is at logic 1 level. As a result of this it is not possible to connect an LED directly to a microcontroller output port. What is required is a resistor to limit the current in the circuit. The nearest physical resistor we can use is 330. Figure 2.8 shows how an LED can be connected to an output port pin in current source mode. In this circuit the LED will be ON when the port output is set to logic 1 Similarly, Figure 2.7 shows how an LED can be connected to an output port pin in current sink mode. In this circuit the LED will be ON when the port output is at logic 0.

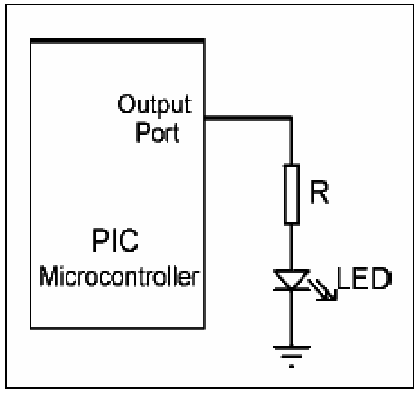


**Figure 2.7** Connecting an LED in current sink mode

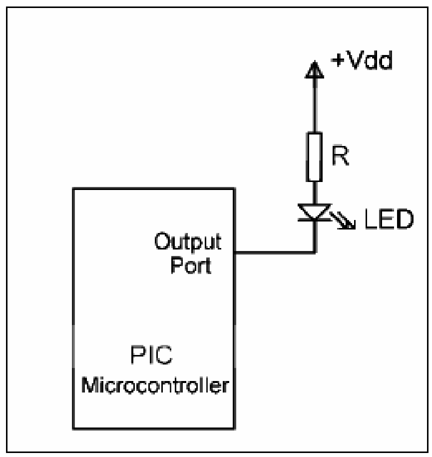


**Figure 2.8** Connecting an LED in current source mode

### 2.2.3 Liquid Crystal Display (LCD)

In many microcontroller-based applications, it is required to display a message or the value of a variable. Basically, three types of displays can be used in practice. These are video displays, 7-segment LED displays, and LCD displays. For this project LCD are used for display purpose. LCDs are alphanumeric displays which are frequently used in microcontroller-based applications. Some of the advantages of LCDs are their low cost and low power consumption. LCDs are ideal in low-power, battery-operated portable applications. These displays come in different shapes and sizes. In this section, are looking at how interfacing for the standard LCDs to a PIC microcontroller and what commands are available to use the LCDs. Table 2.2 shows the pin configuration of the LCD. A description of the pin functions is given below.

**Table 2.2:** Pin configuration of LCD

| Pin No | Name | Function |
|---|---|---|
| 1 | $V_{SS}$ | Ground |
| 2 | $V_{DD}$ | Positive supply |
| 3 | $V_{EE}$ | Contrast |
| 4 | RS | Register select |
| 5 | R/W | Read/write |
| 6 | E | Enable |
| 7 | D0 | Data bit 0 |
| 8 | D1 | Data bit 1 |
| 9 | D2 | Data bit 2 |
| 10 | D3 | Data bit 3 |
| 11 | D4 | Data bit 4 |
| 12 | D5 | Data bit 5 |
| 13 | D6 | Data bit 6 |
| 14 | D7 | Data bit 7 |

- **VSS** is the 0 V or ground. VDD pin should be connected to the positive supply. Although the manufacturers specify a 5 V supply, the module can be operated with as low as 3 V or as high as 6V.

- Pin 3 is named as **VEE** and this is the contrast control pin. This pin is used to adjust the contrast ofthe LCD and it should be connected to a variable voltage supply. A potentiometer is usually connected between the power supply lines with its wiper arm connected to this pin so that the contrast can be adjusted. This pin can be connected to ground if contrast adjustment is not needed.

- Pin 4 is the **Register Select (RS)** and when this pin is LOW, data transferred to the display is treated as commands. When RS is HIGH, character data can be transferred to and from the module.

- Pin 5 is the **read/write (R/W)** pin. This pin is pulled LOW in order to write commands or character data to the LCD module. When this pin is HIGH, character data or status information cannot be read from the module. This pin is usually connected to ground, i.e. the LCD is put into write mode.

- Pin 6 is the **Enable (E)** pin which is used to initiate the transfer of commands or data between the LCD module and the microcontroller. When writing to the display, data is transferred only on the HIGH to LOW transition of this pin. When reading from the display, data becomes available after the LOW to HIGH transition of the enable pin and this data remains valid as long as the enable pin is HIGH.

- Pins 7 to 14 are the eight **data bus lines (D0 to D7).** Data can be transferred between the microcontroller and the LCD module using either an 8-bit interface, or a 4-bit interface. In the latter case, only the upper four data lines (D4 to D7) are used and the data is transferred as two 4-bit nibbles.

When the connections are made between the microcontroller and the LCD, we can simply use the LCDOUT command to send data to the LCD module. Note that the connections between the microcontroller and the LCD can be changed using a set of **DEFINE** commands to assign the LCD pins to the PIC microcontroller. In the following example, PORTB pins 0 to 4 are used for LCD data (i.e. RB0 connected to D4,RB5 connected to D5, etc.), bit 4 of PORTB is connected to the RS pin of the LCD, bit 5 of PORTB is connected to the E pin of the LCD, the LCD is set for 4-bits of operation, and the LCD is assumed to have two rows.

**DEFINE** LCD_DREG PORTB ‘Set LCD data port to PORTB

**DEFINE** LCD_DBIT 0 ‘Set data starting bit to 0

**DEFINE** LCD_RSREG PORTB ‘Set RS register port to PORTB

**DEFINE** LCD_RSBIT 4 ‘Set RS register bit to 4

**DEFINE** LCD_EREG PORTB ‘Set E register port

**DEFINE** LCD_EBIT 5 ‘Set E register bit to 5

**DEFINE** LCD_BITS 4 ‘Set 4 bit operation

**DEFINE** LCD_LINES 2 ‘Set number of LCD rows

The character set of the LCD is given in Table 2.3

**Table 2.3:** LCD commands

| Command | Operation |
|---|---|
| $FE, 1 | Clear display |
| $FE, 2 | Home cursor |
| $FE, $0C | Cursor off |
| $FE, $0E | Underline cursor on |
| $FE, $0F | Blinking cursor on |
| $FE, $10 | Move cursor left by one position |
| $FE, $14 | Move cursor right by one position |
| $FE, $80 | Move cursor to the beginning of first row |
| $FE, $C0 | Move cursor to the beginning of second row |
| $FE, $94 | Move cursor to the beginning of third row |
| $FE, $D4 | Move cursor to the beginning of fourth row |

### 2.2.4 Optocoupler

This device is used because the source and destination are at very different voltage levels, like a microprocessor which is operating from 5V DC but being used to control an electrical appliance which is switching 240V AC. The link between the two must be an isolated one, to protect the microprocessor from overvoltage damage. Relays can of course provide this kind of isolation, but even small relays tend to be fairly bulky compared with ICs and many of today other miniature circuit components. Because they are electro-mechanical, relays are also not as reliable and only capable of relatively low speed operation. Where small size, higher speed and greater reliability are important, a much better alternative is to use an optocoupler. These use a beam of light to transmit the signals or data across an electrical barrier, and achieve excellent isolation. Optocouplers typically come in a small 6-pin or 8-pin IC package, but are essentially a combination of two distinct devices: an optical transmitter, typically a gallium arsenide LED (light-emitting diode) and an optical receiver such as a phototransistor or light-triggered diac. The two are separated by a transparent barrier which blocks any electrical current flow between the two, but does allow the passage of light. Usually the electrical connections to the LED section are brought out to the pins on one side of the package and those for the phototransistor or diac to the other side, to physically separate them as much as possible. This usually allows optocouplers to withstand voltages of anywhere between 500V and 7500V between input and output. Optocouplers are essentially digital or switching devices, so they are best for transferring either on-off control signals or digital data. Analog signals can be transferred by means of frequency or pulse-width modulation. Figure 2.9 show out pin of optocoupler.

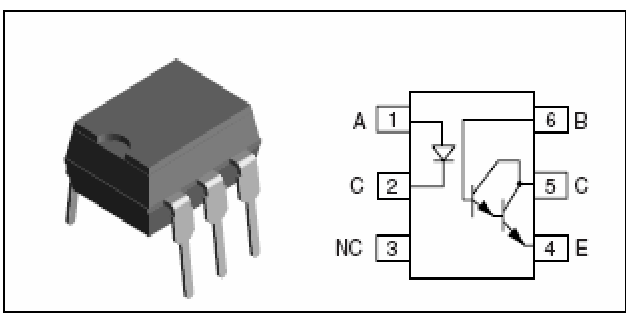


**Figure 2.9:** Pin out for the 6-pin of optocoupler

### 2.2.5 Serial Peripheral Interface Protocol

Serial Peripheral Interface Protocol (SPI) is a synchronous serial communications protocol developed by Motorola. It is designed to allow a single master device to control and communicate with one or more slave devices. Figure 2.10 shows a simple SPI connection structure

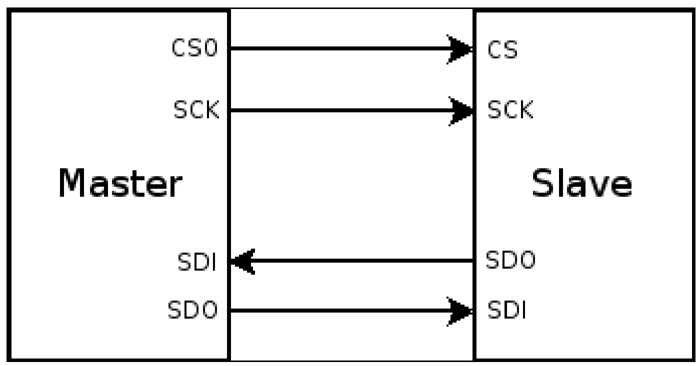


**Figure 2.10:** SPI Connection Structure

There are two control lines and two data lines that are used for SPI communications. Below show function of pin as in Table 2.4.

**Table 2.4:** describes each line and their function.

| Signal | Function |
|---|---|
| CS | Chip Select – allows the master to select the slave or group of slaves with which it will communicate. Master provides output, slaves receive as input |
| SCK | Serial Clock – the synchronous clock signal. Master provides output, slaves receive as input. |
| SDI | Serial Data In – Serial data input line |
| SDO | Serial Data Out – Serial data output line |

There are four different modes of operation for SPI communications. Each mode describes a clock idle polarity and edge select for when data is latched. These modes are shown in Table 2.5 below.

**Table 2.5:** Mode description

| CKP | CKE | SPI Mode | Description |
|---|---|---|---|
| 0 | 0 | 0,1 | SCK idles low, data is latched on high-low clock transition |
| 0 | 1 | 0,0 | SCK idles low, data is latched on low-high clock transition |
| 1 | 0 | 1,1 | SCK idles high, data is latched on low-high clock transition |
| 1 | 1 | 1,0 | SCK idles high, data is latched on high-low clock transition |

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

In this chapter, the equipments used, the procedures and the method for the research is discussed. The main study of this chapter is to determine the overall circuit of the energy management system. The figure 1 has shown the overall system of energy management system. The system consists three main parts include on hardware and software which is power source, controlling unit and monitoring system. Controlling unit is a main of energy management system where control by PIC16F877A.This controller are choose because of instruction set are simple and seamless migration between product families make PIC16F877A microcontrollers the logical choice for designing requiring  flexibility and performance. This controller used to execute the programs that has written or set that is stored in memory. This controller also functions to record and save the data in random access memory (RAM) and calculate the power average used of each appliance that connected to the system.

This system running in condition stand-alone running (without connected to the PC).. In overall this system is operated when the load (electrical appliance) is connected to the power source 240 Vrms, 50Hz. This system only operated in single phase source.

However this system can support more loads by using an extension socket. This system connected to source through switching technique which is used relay to be turn on and off. The current and voltage will be step-down first by interfacing circuit which is used to match with the internal device where the PIC16F877A controller operated in Direct Current (DC) and voltage level at 5V.To ensure the data sent to control unit is digital signal the data of electrical appliance that connected to this system is convert using Analog to Digital converter (ADC). The data from ADC port will be record for every millisecond and save it in random access memory (RAM). The data is power dissipation taken by recording the level of voltage and current. The controller unit will calculate the power average in that interval time and result will display either on LCD display

The signal conditioning circuit is the place conversion process happened, the device that perform signal conversion are often called as transducers or sensors. The conditioning circuit used to convert an AC current signal of 0 to 15 Amps (rms) into a dc voltage of 0 to 5V.For this system two type of sensor are used voltage and current sensor.

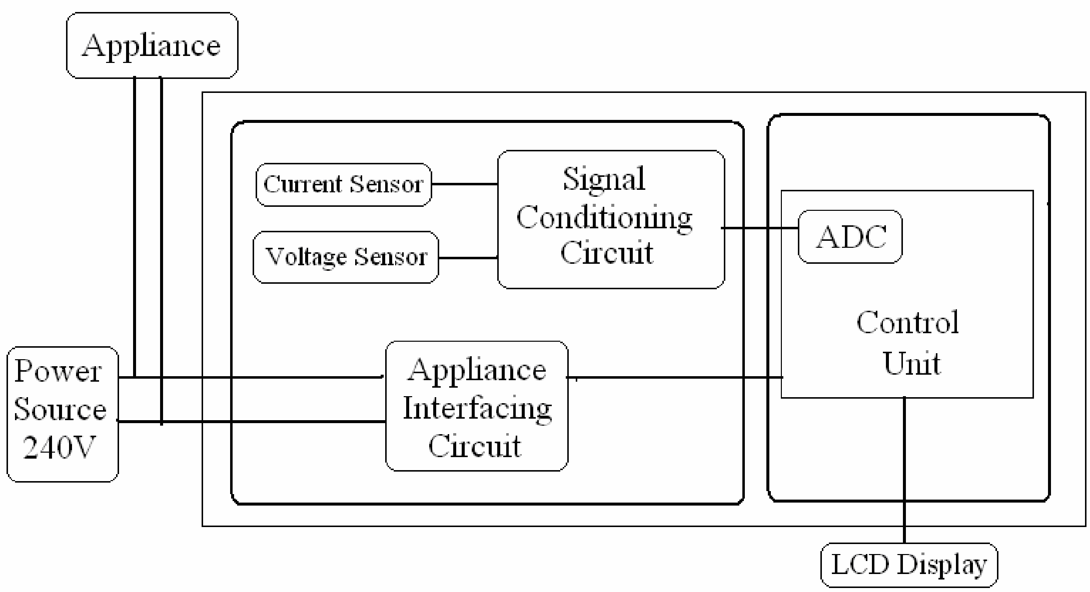


**Figure 3.1:** Overall view of energy management system

## 3.2 Hardware Design

The project involves the design, layout, and fabrication of a custom printed circuit board (PCB). The power consumption meter will be powered from the socket it is currently measuring and thus requires on-board power conversion hardware. The bulk of the hardware focuses on power consumption measurement and data storage. Finally, hardware to display the data and accept user input is also required.

## 3.3 Block Description

### 3.3.1 Load

These energy management systems use any house-hold consumer load. The system investigating various loads with rated power consumptions of around 9 KW such as water heater, lamp and etc.

### 3.3.2 Power Supply Circuit

For this circuit utilize an appropriate power supply that converts the 240 V, 50 Hz AC voltage to appropriate DC values (mainly 5 volt, and additionally 12 volts if required) to power the ADE, PIC, Relay, and LCD circuit. Batteries and adapter also are looking for providing power for this circuit. The main purpose of power supply module is to be as power source to the system.

### 3.3.3 Energy Measurement Circuit

The Energy Measurement circuit is responsible for direct current, voltage, and power angle measurements, and from them, determining real and reactive power consumption. The Energy Measurement circuit must be capable of relaying these measured and calculated values to the microcontroller via a serial bus. The heart of the Energy Measurement subsystem is Analog Devices Energy Meter p/n ADE7753. The ADE7753 offers analog voltage and current inputs, and an SPI serial interface. Both voltage and current inputs require a 0 to 0.5V analog input. The analog inputs are sampled by ADCs within the ADE7753, and their magnitudes and phases are used to digitally calculate real, reactive, and complex power in the line. The current sensing circuit consists of a single shunt resistor rated at 0.02 Ohms and 5W.The resistor is located in the Neutral wire, and is tapped at both sides. The load side is connected to pin V1P, and the source side is connected to pin V1N. Maximum current to be drawn through the line is 15A, and so voltage across the current sense resistor will range from zero to 0.3VAC. Maximum sustained power dissipation in the resistor when 15A is being drawn will be approximately 4.5W, which is within the resistor s rated operation. The voltage sensing circuit consists of a high-impedance bridge between the Hot and Neutral wires. Two high-precision resistors rated at 470k Ohms and 680 Ohms are connected in series between the Hot and Neutral lines as shown in figure 4.1 Pins V2P and V2N are connected across the 680 Ohm resistor. Note that at 240VAC line voltage, the current leakage through the voltage sensing bridge is approximately 0.5mA, and therefore power dissipation in the voltage sense resistors is not a concern. In Appendix B shows the circuits diagram of the Energy Measurement system and Table 3.1 below outlines in detail each pin connection of the device

**Table 3.1:** Energy Measurement Circuit Pin Assignment

| Pin | Connection | Description |
|---|---|---|
| RESET | Microcontroller RA4 | Reset pin |
| DIN | Microcontroller SDO | Serial interface data input |
| DOUT | Microcontroller SDI | Serial interface data output |
| SCLK | Microcontroller SCK | Serial interface clock |
| CS' | Microcontroller RC6 | Serial interface chip select |
| CLKOUT | Clock Gen | Chip clock. Parallel AT crystal @ 3.579545MHz provide clock source |
| CLKIN | Clock Gen | |
| IRQ' | NC | |
| SAG' | NC | |
| 2X | NC | |
| CF | NC | |
| DGND | Dig. Ground | Digital Ground Reference. Provides ground reference for the digital circuitry |
| REF | Ana. Gnd w/ 10uF decoupling | On-chip voltage reference |
| AGND | Ana. Ground | Analog Ground Reference. Provides ground reference for analog circuitry |
| V2P | Neutral Wire | Analog inputs for channel 2, used with the voltage transducer |
| V2N | Voltage Sense | |
| V1P | Neutral Wire (load side) | Analog inputs for channel 1, used with the current transducer |
| V1N | Neutral Wire (source side) | |
| AVDD | +5V Power | Analog voltage supply. Provides supply voltage for analog circuitry |
| DVDD | +5V Power | Digital voltage supply. Provides supply voltage for digital circuitry |